Using PRISM Climate Grids and GIS for Extreme Precipitation Mapping

George H. Taylor, State Climatologist
Oregon Climate Service
316 Strand Ag Hall
Oregon State University
Corvallis OR 97331-2209

Tel: 541-737-5705
Fax: 541-737-5710
E-mail: taylor@coas.oregonstate.edu
Web: http://www.ocs.orst.edu

BIOGRAPHICAL SKETCH

Since 1989 Mr. Taylor has served as State Climatologist for Oregon, and is a faculty member at Oregon State University (OSU). He received B.A. degrees in Mathematics and Geography from the University of California and an M.S. in Meteorology from the University of Utah. He is recognized as a Certified Consulting Meteorologist by the American Meteorological Society.

Among his recent projects are the following:

- Co-manager of climate mapping products for the Spatial Climate Analysis Service (SCAS) at OSU. SCAS is currently responsible for nearly all major climate mapping efforts at the Federal level in the United States. SCAS data are certified as the official climate data sets for the USDA, and are now the only spatial climate data so certified at the Federal level. Examples of national programs that are, or will soon, use SCAS spatial data include USDA National Resource Inventory, USDA Conservation Reserve Program, USDA Wetlands Reserve Program, NOAA Office of Global Programs, and the U.S. Global Change Research Program.

- Project scientist for a number of Probable Maximum Precipitation studies, including recent projects in Saskatchewan, Canada; southwest British Columbia; and Lake Chelan, Washington.

- Principal Investigator for projects to map storm event precipitation for three large flood events in the Pacific Northwest.

- Climatologist for several projects to develop new precipitation frequency-duration products for the United States, including western Washington, Oregon, the southwest interior, and the Ohio Valley.
- Wrote analysis of streamflow forecasting for the Klamath Basin, Oregon, including development of new instrumentation sets and incorporation of GIS technology into forecasts.

- Author of two books and numerous articles on climate and factors influencing climate, such as the El Niño Southern Oscillation and Pacific Decadal Oscillation.

Use of PRISM Climate Grids and Geographic Information Systems (GIS) for Extreme Precipitation Mapping

George H. Taylor and Christopher Daly
Oregon State University
Corvallis Oregon 97331-2209

Extreme precipitation information is of interest for a variety of purposes, including public safety, water supply, dam design and operation, and transportation planning. Two common parameters calculated for extreme precipitation purposes are probable maximum precipitation (PMP) and intensity-duration-frequency (IDF). The definition of PMP is "theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given area at a particular geographical location at a certain time of the year." PMP estimates are used to calculate the probable maximum flood (PMF), which in turn is used to evaluate the adequacy of hydraulic structures. IDF calculations are used in a variety of precipitation-related tasks, including PMP. The primary agency responsible for establishing standards for PMP and IDF has been the National Oceanic and Atmospheric Administration (NOAA) – see, for example, U.S. Department of Commerce(1994). Specific regional and local analyses have generally been performed by local agencies or private contractors.

Historically, computations of these parameters have been accomplished using mostly manual techniques (e.g., hand-drawn maps). Advances in spatial climate mapping and geographical information systems (GIS) technology have created new opportunities for mapping extreme precipitation. Using GIS software and climate grids created using PRISM, new approaches to extreme precipitation mapping have been applied to specific locations with good success. In addition to automating analytical processes, thereby saving time, the new techniques have been shown to produce more consistent and defensible coverages (digital map layers) than those of previous analyses.

PRISM (Parameter-elevation Regressions on Independent Slopes Model) is an expert system that uses point data and a digital elevation model (DEM) to generate gridded estimates of climate parameters (Daly et al., 2002). Unlike other statistical methods in use today, PRISM was written by a meteorologist specifically to address climate. PRISM is well-suited to mountainous regions, because the effects of terrain on climate play a central role in the model's conceptual framework. We call it an expert system, because it attempts to mimic the process an expert would use to map climate parameters. The user interacts with the process through a graphical interface.

The general procedure for estimating 24-hour PMP includes the following steps:

1) Collect hourly and daily precipitation data for major historical storms and select major storms for analysis;
2) Obtain or develop station information representing computed or estimated 100-year 24-hour (or other averaging period) precipitation amounts (see Figure 1);
3) For each storm, calculate the percent of 100-year 24-hour precipitation observed at each available station

Using PRISM Climate Grids and GIS for Extreme Precipitation Mapping

George Taylor and Chris Daly
Oregon State University

OCS
OREGON CLIMATE SERVICE

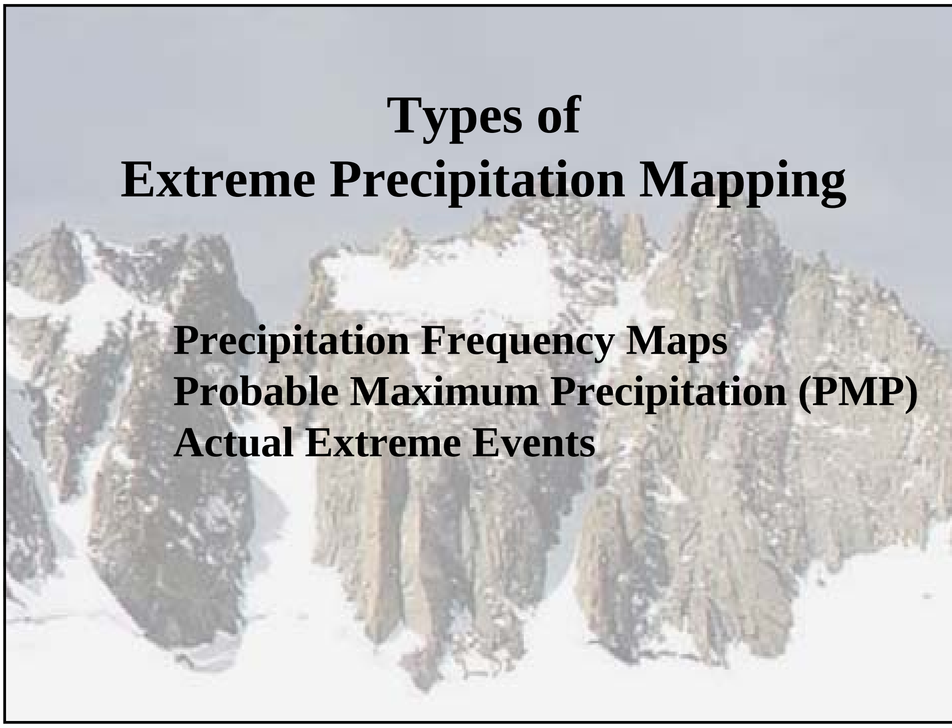
SCAS
SPATIAL CLIMATE ANALYSIS SERVICE

Climate Mapping with PRISM

PRISM

Parameter-elevation Regressions on Independent Slopes Model

- Generates gridded estimates of climatic parameters
- Moving-window regression of climate vs. elevation for each grid cell
- Uses nearby station observations
- Spatial climate knowledge base (KBS) weights stations in the regression function by their climatological similarity to the target grid cell

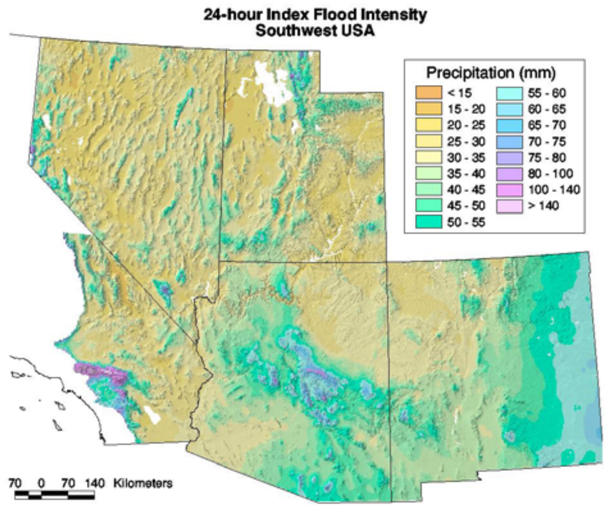


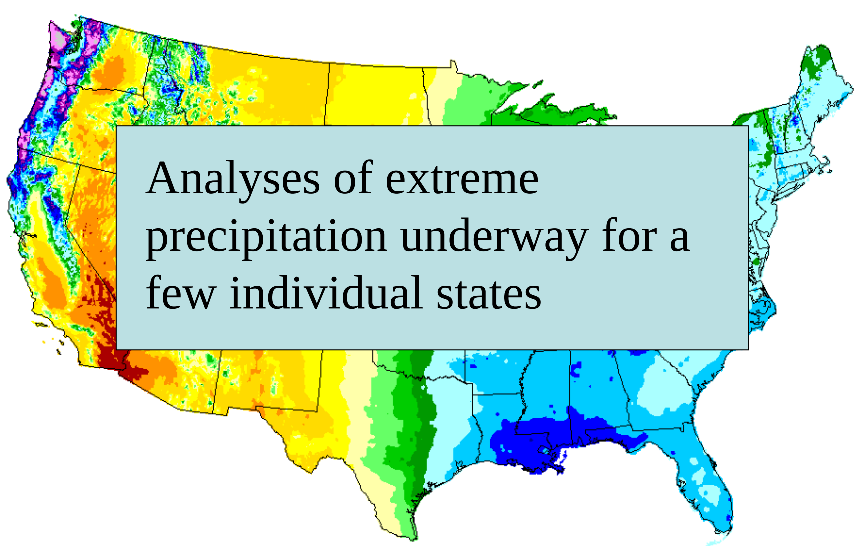
Precipitation Frequency Maps

- Existing products very old (TP-40 - early 1960s; NOAA-2 - early 1970s
- Used for a variety of purposes, including dam safety and civil engineering
- Working with the NWS-HDSC on updating these critical products for NRCS engineering work

TP-40/NOAA Atlas 2 Precipitation Frequency Update (NOAA NWS HDSC)

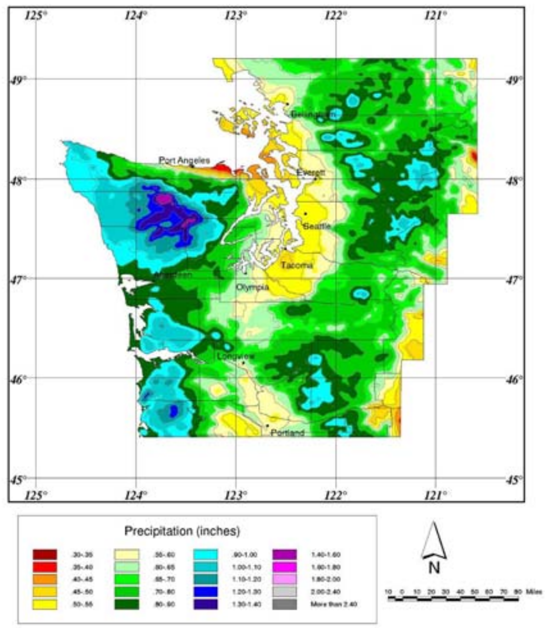
- Built upon NRCS mapping project
- Semi-arid Southwest Ohio Valley
- Remainder of country needs to be mapped



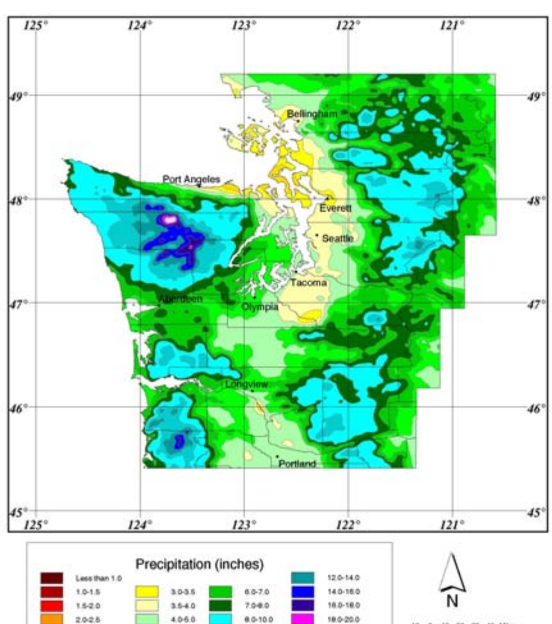


Analyses of extreme precipitation underway for a few individual states

2-year 2-hour Precipitation, Western Washington



100-year 24-hour Precipitation, Western Washington



Probable Maximum Precipitation (PMP)

“theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given area at a particular geographical location at a certain time of the year.”

Probable Maximum Precipitation (PMP)

Uses:

1. Dam safety
2. Other

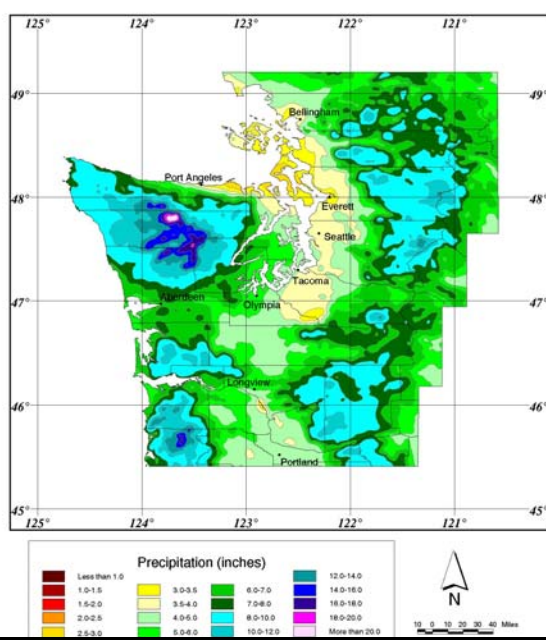
PMP Procedure

1) Collect hourly and daily precipitation data for major historical storms and select major storms for analysis;

2) Obtain or develop station information representing computed or estimated 100-year 24-hour (or other averaging period) precipitation amounts;

3) For each storm, calculate the percent of 100-year 24-hour precipitation observed at each available station

100-year 24-hour Precipitation, Western Washington



PMP Procedure

1) Collect hourly and daily precipitation data for major historical storms and select major storms for analysis;

2) Obtain or develop station information representing computed or estimated 100-year 24-hour (or other averaging period) precipitation amounts;

3) For each storm, calculate the percent of 100-year 24-hour precipitation observed at each available station

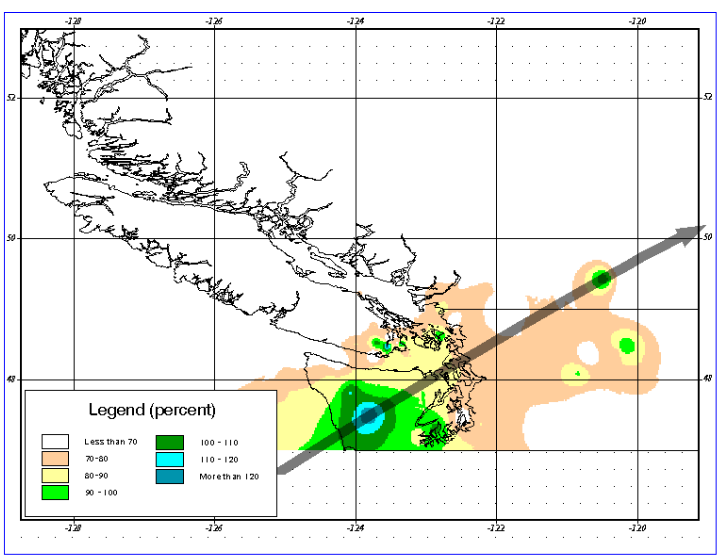


Figure 6 – Percent of daily observed precipitation compared to 100-year precipitation, January 1935

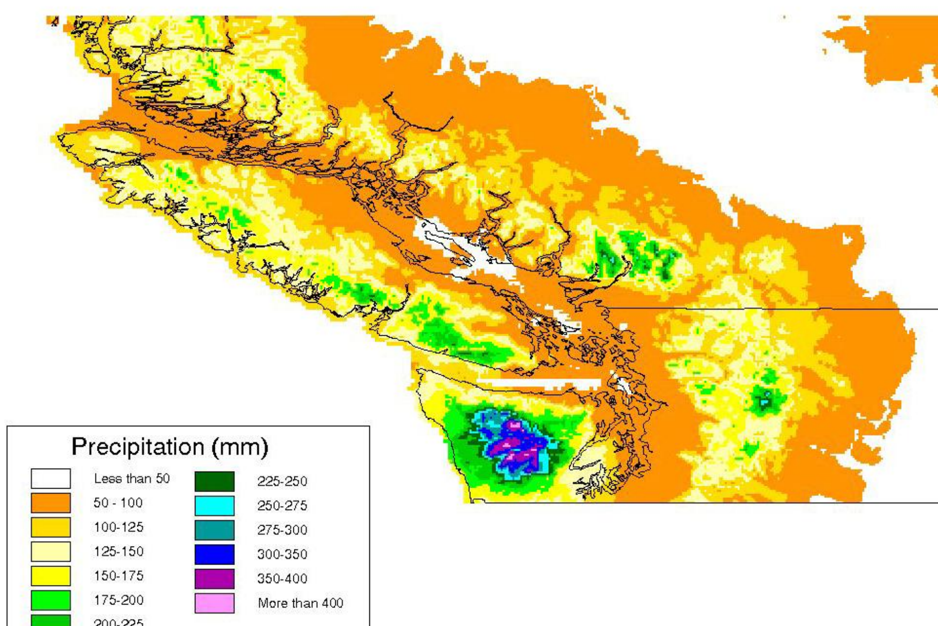
PMP Procedure

4) Create a GIS coverage representing the percentage of 100-year precipitation using the station data above;

5) Create isohyetal maps of maximum 24-hour precipitation for each selected historical storm using the coverages from 2) and 4);

6) Estimate the 100-year convergence precipitation (defined as the maximum precipitation component operating independent of terrain influences) using a spatial grid and GIS;

Maximum One-Day Precipitation, January 1935



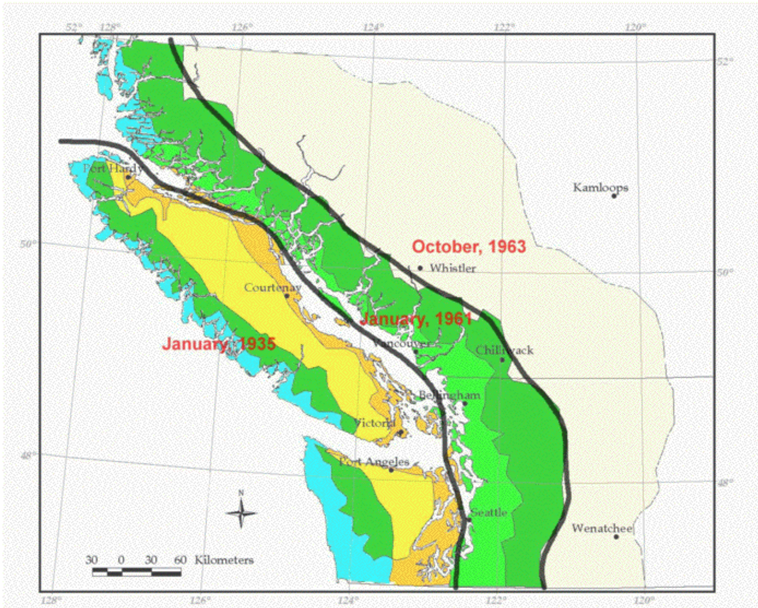


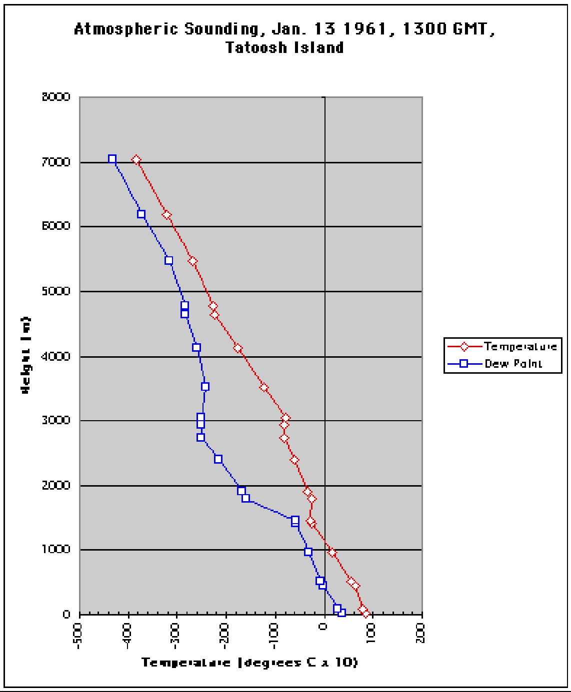
Figure 9. Map of controlling storms for Southwest British Columbia PMP. The color-shaded areas indicate climate zones identified by Schaefer (2001)

PMP Procedure

7) Determine the convergence precipitation from significant historical storms;

8) Maximize the convergence component of historical storms using a set of maximization factors, particularly the ratio of maximum observed dew point to observed dew point during each storm;

9) Transpose maximized convergence from each storm across a spatial grid using variations in maximum persisting dew point applying both vertical and horizontal transposition limits;

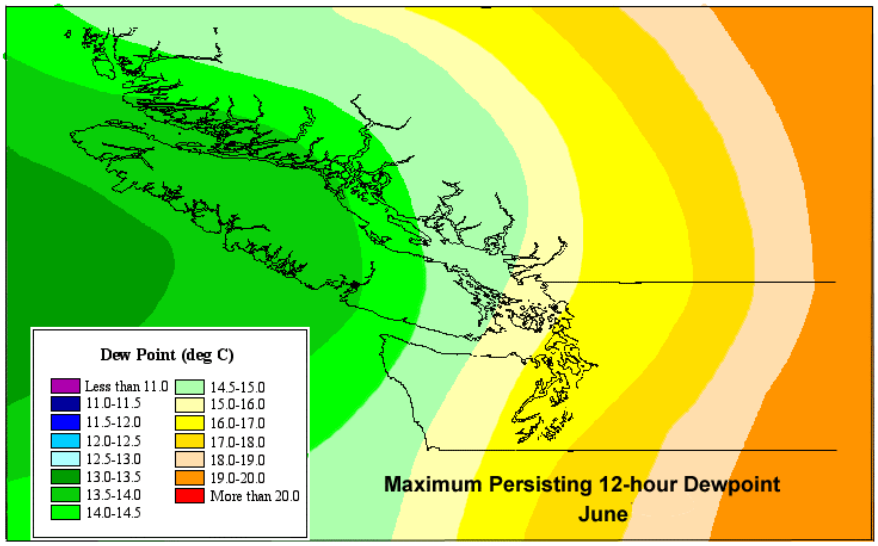


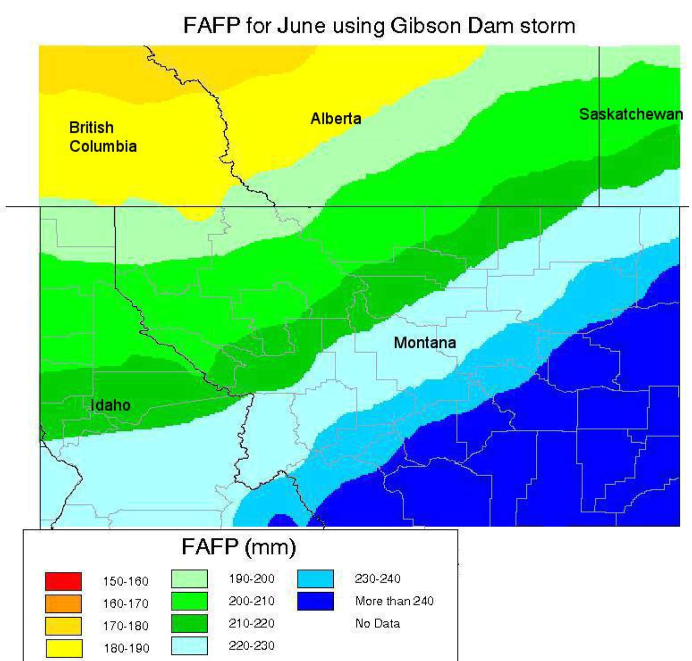
PMP Procedure

7) Determine the convergence precipitation from significant historical storms;

8) Maximize the convergence component of historical storms using a set of maximization factors, particularly the ratio of maximum observed dew point to observed dew point during each storm;

9) Transpose maximized convergence from each storm across a spatial grid using variations in maximum persisting dew point applying both vertical and horizontal transposition limits;


Dew Point (deg C)
Less than 11.0
11.0-11.5
11.5-12.0
12.0-12.5
12.5-13.0
13.0-13.5
13.5-14.0
14.0-14.5
14.5-15.0
15.0-16.0
16.0-17.0
17.0-18.0
18.0-19.0
19.0-20.0
More than 20.0
Maximum Persisting 12-hour Dewpoint
June


FAFP for June using Gibson Dam storm
British Columbia
Alberta
Saskatchewan
Montana
Idaho
FAFP (mm)
150-160
160-170
170-180
180-190
190-200
200-210
210-220
220-230
230-240
More than 240
No Data

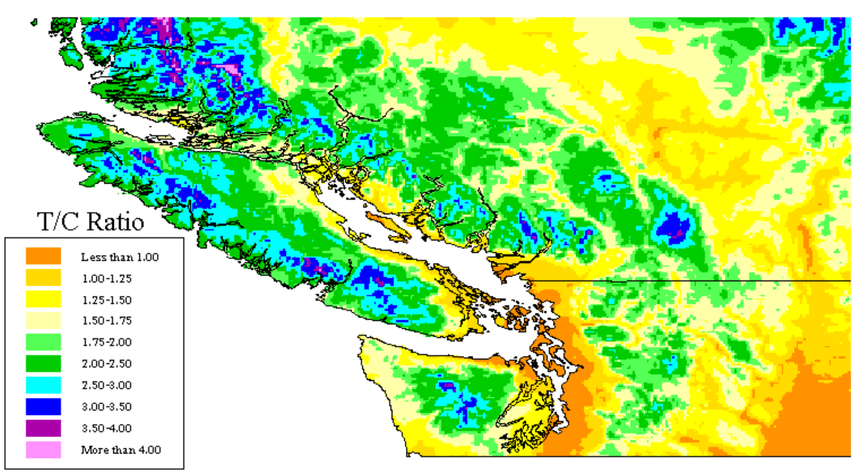
PMP Procedure

10) Estimate the ratio of 100-year total precipitation to 100-year convergence precipitation (T/C) using the above data;

11) Estimate the variation in values of the storm intensity factor, M, to derive the orographic factor, K; and

12) Determine the total PMP by multiplying GIS coverage of convergence PMP by grid of K.

13) Add in effects of snow melt, if any.



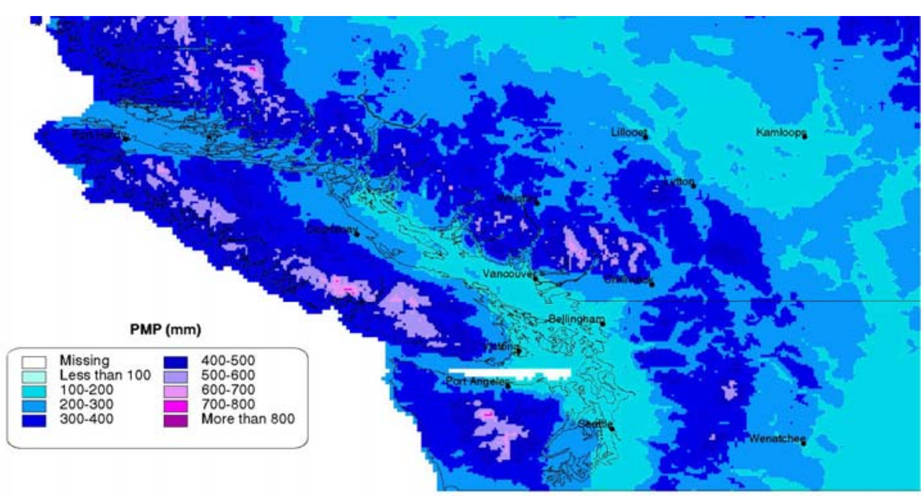
PMP Procedure

10) Estimate the ratio of 100-year total precipitation to 100-year convergence precipitation (T/C) using the above data;

11) Estimate the variation in values of the storm intensity factor, M, to derive the orographic factor, K; and

12) Determine the total PMP by multiplying GIS coverage of convergence PMP by grid of K.

13) Add in effects of snow melt, if any.



Probable Maximum Precipitation, 24 hours, Southern British Columbia

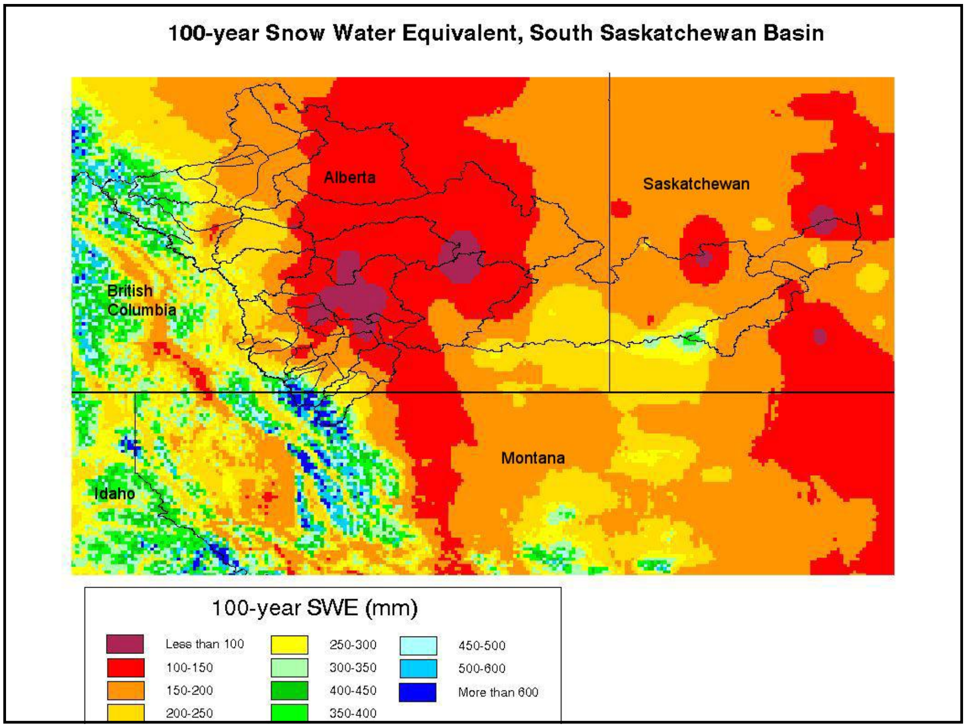
PMP Procedure

10) Estimate the ratio of 100-year total precipitation to 100-year convergence precipitation (T/C) using the above data;

11) Estimate the variation in values of the storm intensity factor, M, to derive the orographic factor, K; and

12) Determine the total PMP by multiplying GIS coverage of convergence PMP by grid of K.

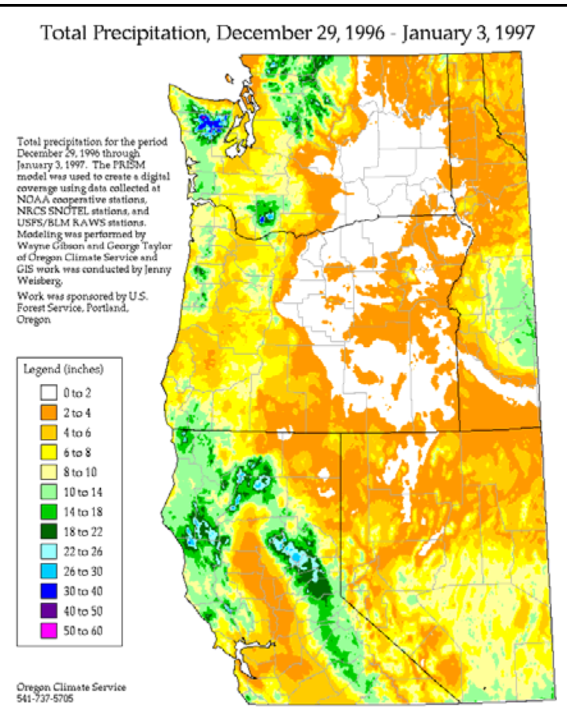
13) Add in effects of snow melt, if any.

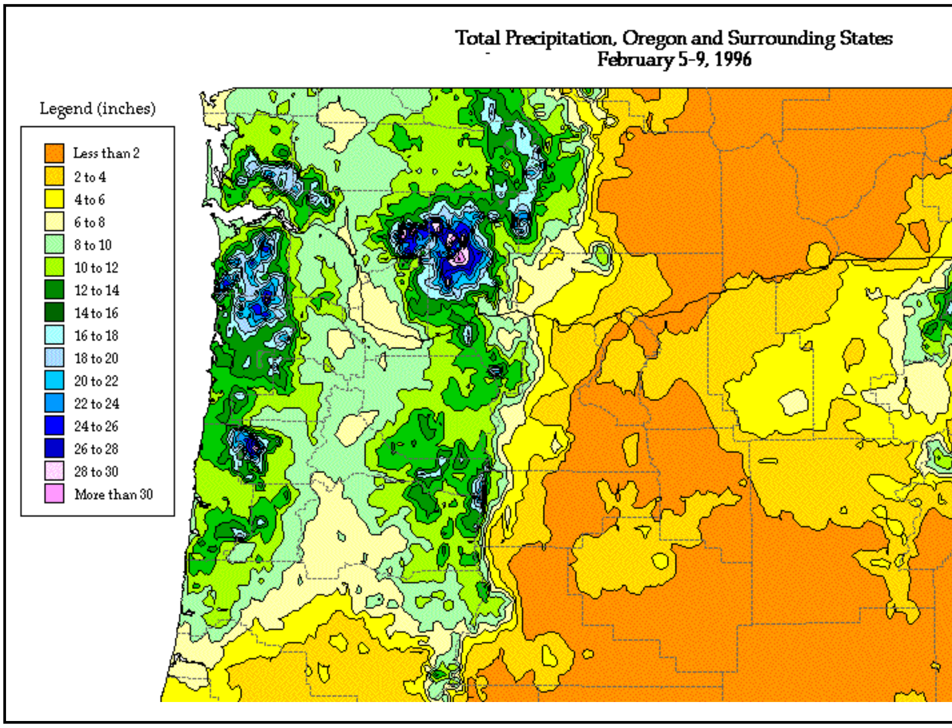


Mapping Actual Extreme Events

Multi-day floods

Single-day or shorter events




Total Precipitation, Oregon and Surrounding States
February 5-9, 1996
Legend (inches)
Less than 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
18 to 20
20 to 22
22 to 24
24 to 26
26 to 28
28 to 30
More than 30


The End

4) Create a GIS coverage representing the percentage of 100-year precipitation using the station data above (Figure 2);
5) Create isohyetal maps of maximum 24-hour precipitation for each selected historical storm using the coverages from 2) and 4) – Figure 3.
6) Estimate the 100-year convergence precipitation (defined as the maximum precipitation component operating independent of terrain influences) using a spatial grid and GIS (Figure 3);
7) Determine the convergence precipitation from significant historical storms;
8) Maximize the convergence component of historical storms using a set of maximization factors, particularly the ratio of maximum observed dew point to observed dew point during each storm;
9) Transpose maximized convergence from each storm across a spatial grid using variations in maximum persisting dew point applying both vertical and horizontal transposition limits;
10) Estimate the ratio of 100-year total precipitation to 100-year convergence precipitation (T/C) using the above data (Figure 4);
11) Estimate the variation in values of the storm intensity factor, M, to derive the orographic factor, K; and
11) Determine the total PMP by multiplying GIS coverage of convergence PMP by grid of K (Figure 5).

The figures shown were developed for two PMP projects in the Pacific Northwest: PMP for Southwestern British Columbia, for B.C. Hydro of Canada; and Extreme Precipitation (IDF) for Western Washington for the Washington Department of Transportation.

References

Daly, C., W. P. Gibson, G.H. Taylor, G. L. Johnson, P. Pasteris, 2002. A Knowledge-based Approach to Statistical mapping of Climate. Climate Research, 22, 99-113.

MGS Engineering and Oregon Climate Service (2001), Spatial Mapping of 100-Year and 1000-Year Precipitation for 6-Hour, 24-Hour, and 72-Hour Durations for Southwest British Columbia. Report to BC Hydro.

Schaefer, M., 2001. Catalog Of Extreme Storms for use in Probable Maximum Precipitation Study for Southwest British Columbia. MGS Engineering, Olympia, WA.

U.S. Department of Commerce, 1994. Probable Maximum Precipitation – Pacific Northwest States. Hydrometeorological Report No. 57 (HMR-57), Silver Spring, MD.

100-year 24-hour Precipitation, Western Washington

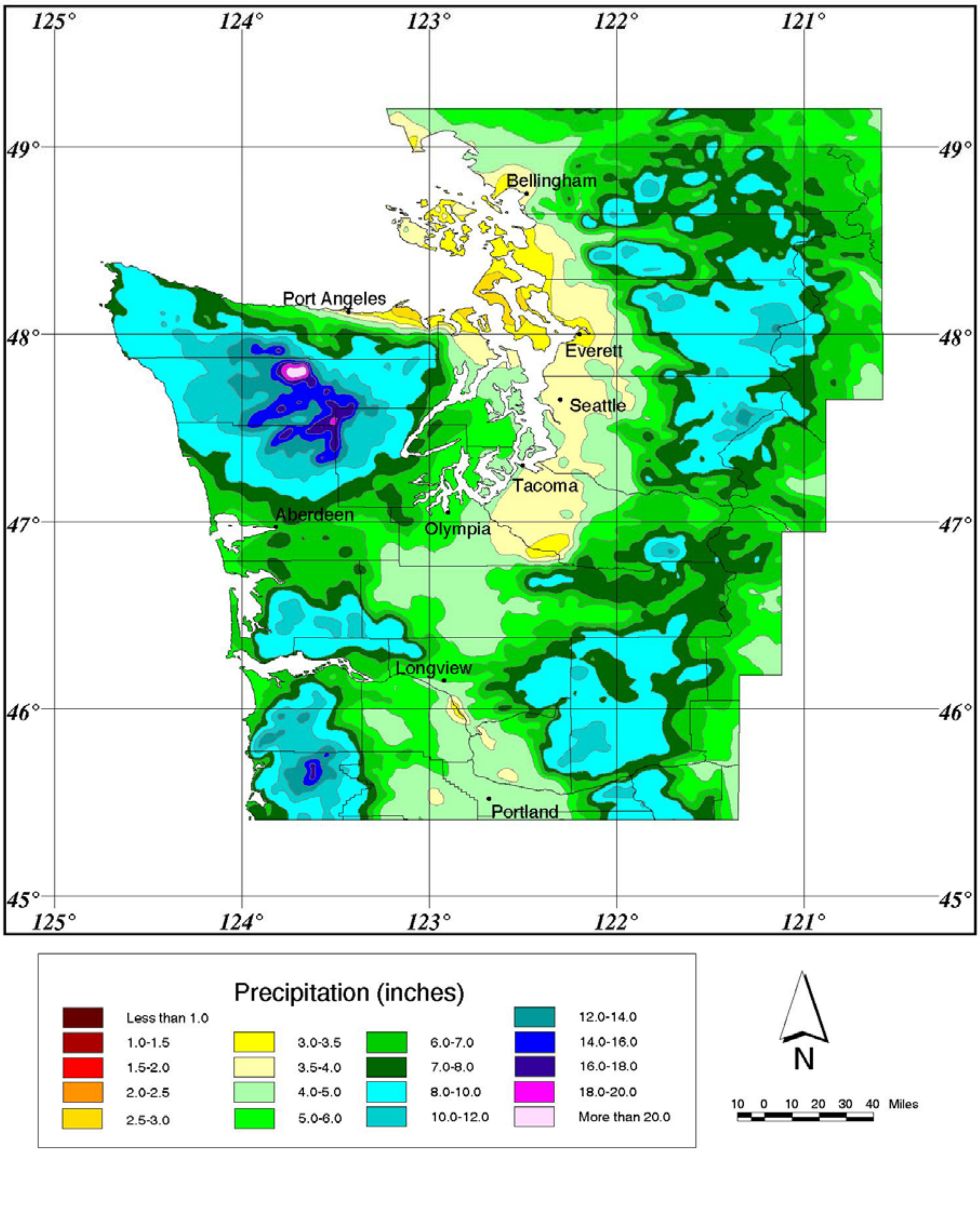


Figure 1. Example of a 100-year, 24-hour Maximum Precipitation Map

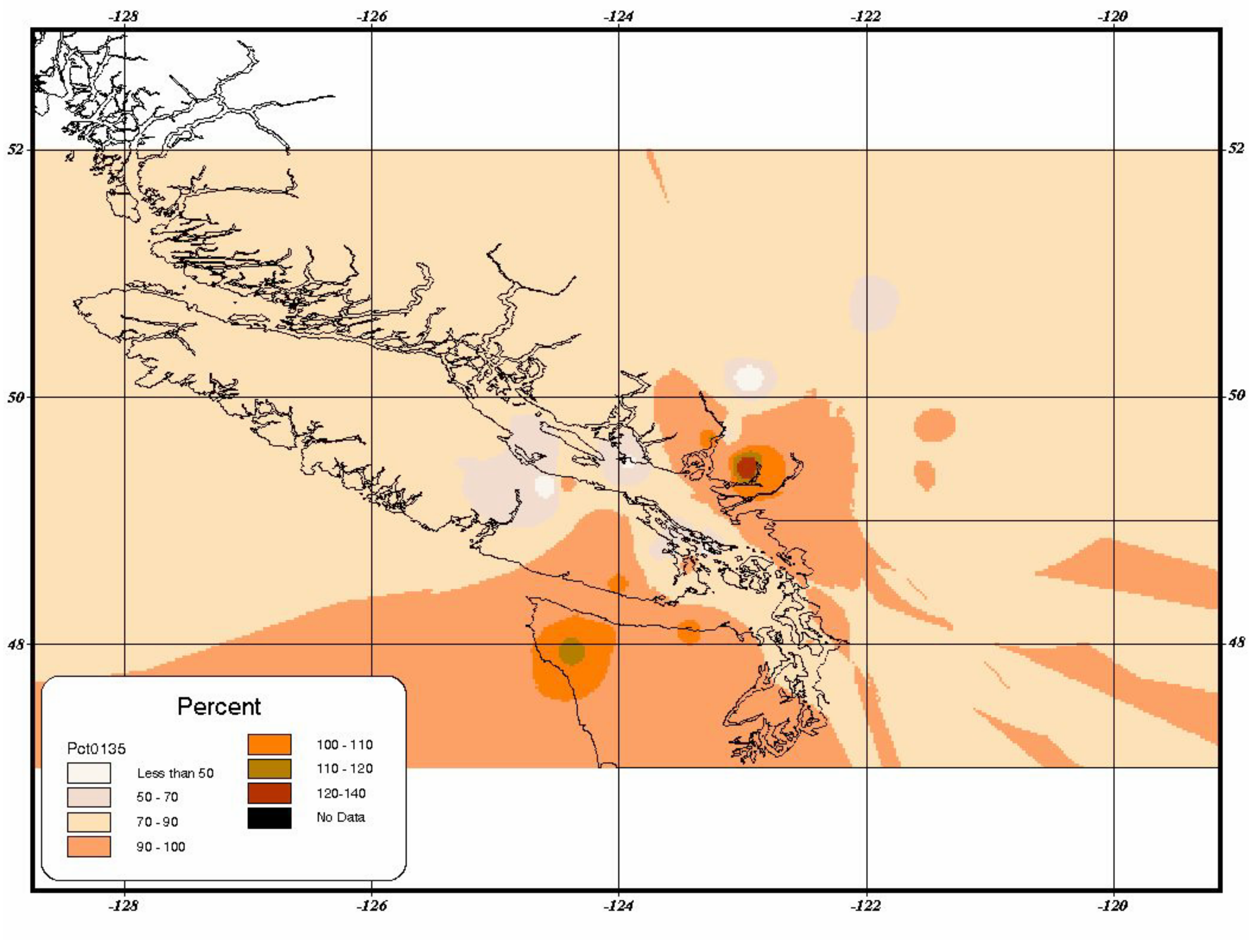


Figure 2. Estimated Percent of 100-year Precipitation Observed During a Storm

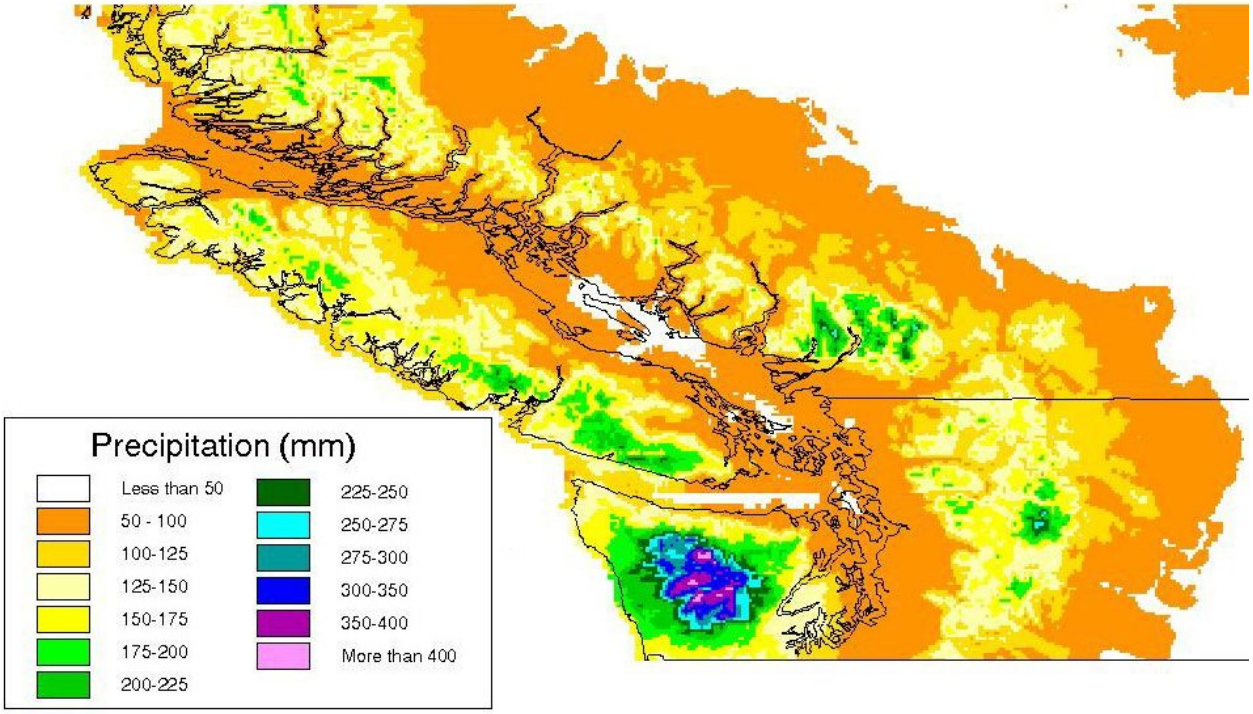


Figure 3. Estimated One-Day Precipitation for a Storm Event

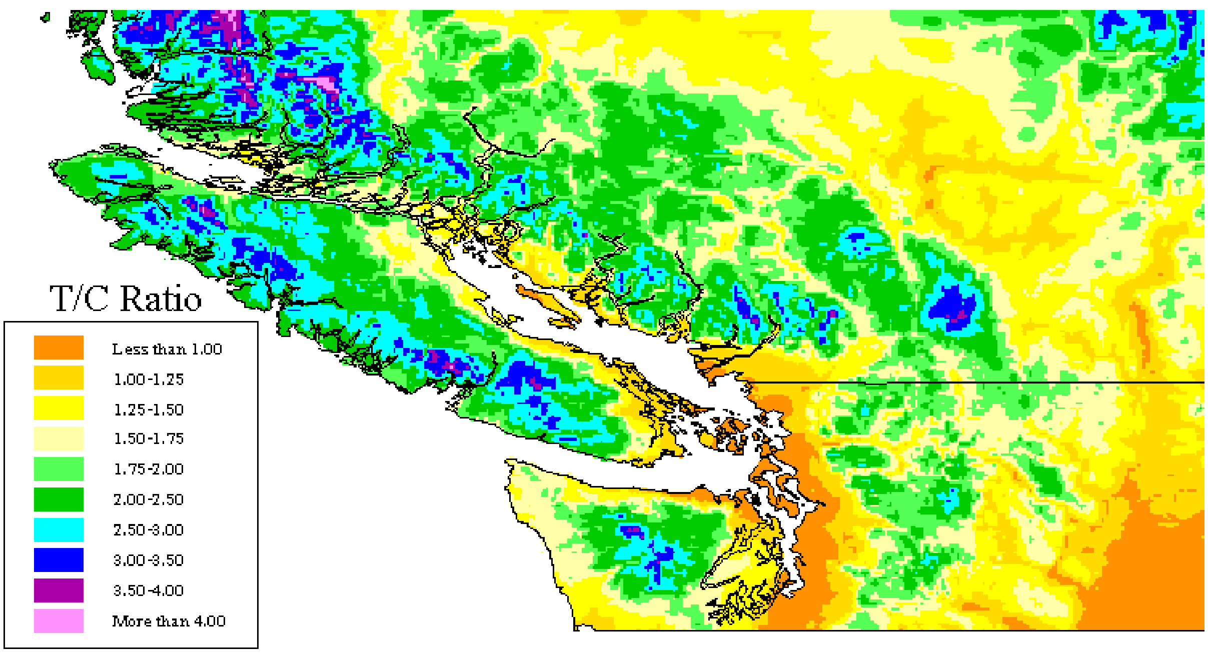


Figure 4. T over C (total to convergence precipitation) for Southwest British Columbia and Northwest Washington

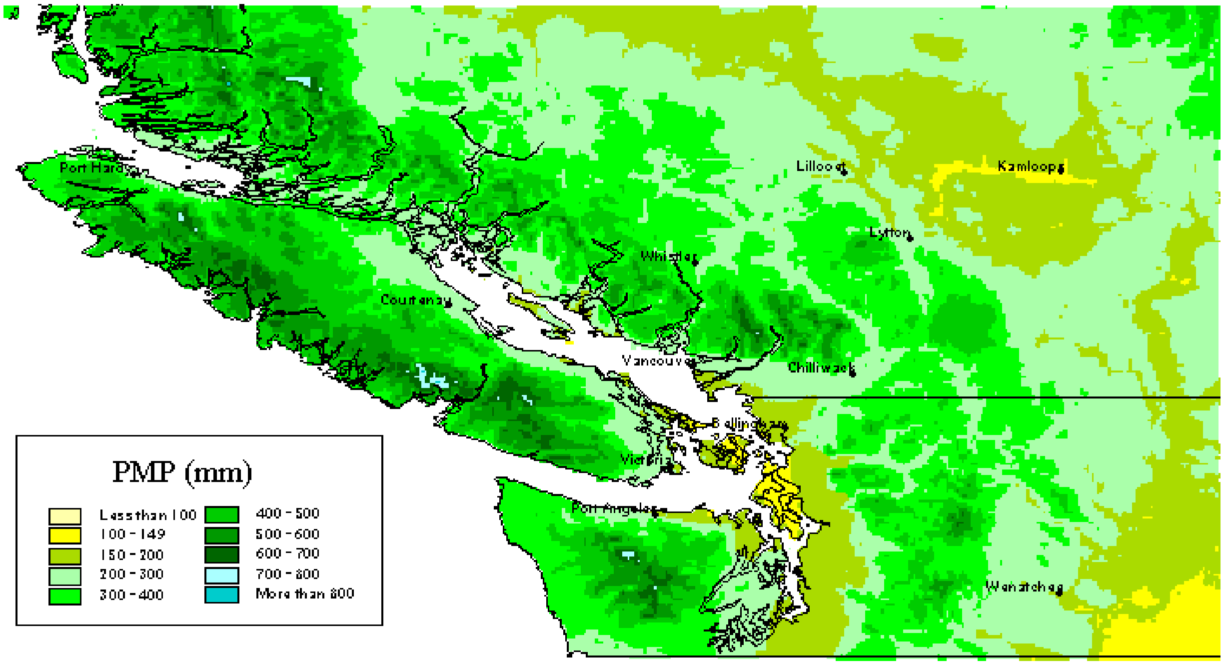


Figure 5. Probable maximum Precipitation (PMP) for Southwest British Columbia and Northwest Washington